International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Effect of Glass Powder in Cement Concrete

ABHISHEK UPADHYAY[1], ANKIT[2], ARVIND KUMAR MISHRA[3], KULDEEP RATHAUR[4], MR. DIVAKAR SINGH[5]

[1]DEPARTMENT OF CIVIL ENGINEERING
BANSAL INSTITUTE OF ENGINEERING AND TECHNOLOGY, LUCKNOW, INDIA
[2]DEPARTMENT OF CIVIL ENGINEERING
BANSAL INSTITUTE OF ENGINEERING AND TECHNOLOGY, LUCKNOW, INDIA
[3]DEPARTMENT OF CIVIL ENGINEERING
BANSAL INSTITUTE OF ENGINEERING AND TECHNOLOGY, LUCKNOW, INDIA
[4]DEPARTMENT OF CIVIL ENGINEERING
BANSAL INSTITUTE OF ENGINEERING AND TECHNOLOGY, LUCKNOW, INDIA
[5]DEPARTMENT OF CIVIL ENGINEERING
BANSAL INSTITUTE OF ENGINEERING AND TECHNOLOGY, LUCKNOW, INDIA

---***---

ABSTRACT - In a growing country like India a huge amount of industrial waste are polluting the environmental. The utilization of waste glass powder in cement concrete has gained increasing attention as a sustainable approach to recycling glass waste and reducing environmental impact. Waste glass, when ground into fine powder, can act as a supplementary cementitious material due to its pozzolanic properties, partially replacing cement in concrete mixes. Results demonstrate that glass powder incorporation not only reduces cement consumption but also improves the durability of concrete, making it a promising alternative for sustainable concrete production. This research provides insights into effective waste management practices, promotes circular economy principles, and contributes to the development of eco-friendly construction materials.

***Key Words*:** Cement replacement, Waste Glass powder, Concrete, Water absorption, Durability, Eco-friendly.

1.INTRODUCTION

The construction industry has historically been a significant contributor to environmental challenges, with cement production alone accounting for approximately 8% of global CO_2 emissions. In response to the growing emphasis on sustainability, substantial research efforts have been directed toward reducing cement consumption without compromising the strength and durability of concrete.

One innovative approach involves the utilization of waste glass, a material that is typically discarded in landfills. Globally, around 130 million tons of waste glass are generated annually, with a considerable portion remaining unrecycled. When processed into a fine powder, waste glass can serve as a partial replacement for cement, providing an environmentally friendly alternative for construction materials.

Several studies have demonstrated that incorporating finely ground glass powder into concrete significantly reduces water absorption and permeability, thereby enhancing the material's resistance to water-induced damage and improving its overall durability. These benefits are largely attributed to the pozzolanic properties of glass powder, stemming from its high silica (SiO_2) content.

Despite the generation of nearly 3 million tons of glass waste annually in India, only about 35% is recycled. The remainder is either deposited in landfills or downcycled into low-value construction materials, representing a missed opportunity for sustainable material reuse. In 2016, global glass production reached approximately 140 million tons, with major contributions from China (50%), Europe (15%), and North America (10%).

Research suggests that replacing 5–20% of cement with glass powder can achieve an optimal balance between mechanical performance and environmental benefits. Practical applications, such as the Edge Building in Amsterdam and various infrastructure projects in India and Australia, demonstrate the successful integration of glass powder in sustainable construction practices.

This review aims to consolidate the existing body of research on the use of glass powder as a partial cement substitute, examining its effects on water absorption, permeability, workability, and overall durability. By synthesizing findings from both experimental studies and real-world implementations, the paper highlights the potential of glass powder to contribute meaningfully to the development of eco-friendly, high-performance concrete materials.

2. LITERATURE REVIEW

Recent studies have consistently demonstrated that waste glass powder (WGP) has significant potential as a supplementary cementitious material (SCM) in concrete, improving both the sustainability and mechanical properties of concrete.

Zhou & Zhu (2023) et al highlighted despite its benefits, challenges remain in the consistent quality and performance of WGP concrete. Variations in glass composition (e.g., soda-lime glass versus borosilicate glass) can impact the reactivity of the powder. Additionally, the need for specific processing techniques to achieve fine particle sizes presents economic challenges in scaling up the use of WGP in commercial concrete production.

Du & Tan (2022) and Zhou & Zhu et al (2023) suggests that the efficiency of WGP as a pozzolanic material depends significantly on its particle size. Finer particles increase the surface area available for the pozzolanic reaction, resulting in a more dense and stronger concrete matrix. Grinding the glass to a particle size below 100 microns maximizes its reactivity and contributes to improved strength properties. However, the practical challenge of grinding waste glass to this fine size may increase processing costs, which requires careful consideration for large-scale applications.

Alsaif et al. (2021) reported that WGP has been shown to enhance the compressive strength of concrete, especially at low replacement levels (typically 10–20%). concrete with up to 15% WGP replacement exhibited enhanced compressive strength compared to traditional concrete, due to the formation of additional C-S-H gel. However, higher replacement levels (over 20%) can lead to a reduction in strength due to the reduced cement content.

Kurama & Kaya et al (2020) reported that incorporating WGP has been shown to improve the durability of concrete, particularly its resistance to chemical attacks. The pozzolanic reaction helps mitigate the effects of alkali-silica reaction (ASR), Concrete containing WGP also demonstrates increased resistance to sulfate and chloride penetration, making it suitable for aggressive environmental conditions, such as marine or industrial environments. The inclusion of WGP can help reduce the long-term degradation of concrete, extending the service life of structures.

Ling & Poon (2020) and Soliman & Tagnit-Hamou et al (2019) confirm that WGP is primarily composed of silica (SiO_2), which is responsible for its pozzolanic activity. When finely ground, WGP reacts with calcium hydroxide ($Ca(OH)_2$) produced during the hydration of cement to form calcium silicate hydrate (C-S-H) gel, which contributes to the strength and durability of concrete, clear and colored waste glass powders exhibit pozzolanic activity, although the reactivity can vary based on the particle size and type of glass used.

According to **Shafigh et al. (2020)**, one of the additional benefits of using WGP in concrete is improved workability, as the fine particles enhance the flowability of the mix. This can result in better ease of placement and finishing of the concrete. the water demand of WGP concrete is reduced compared to conventional concrete, without compromising its workability

3.MATERIALS

3.1 MATERIAL USED AND PROPERTIES:

3.1.1 PORTLAND POZZOLANA CEMENT (PPC): Cement is a vital construction material acting the primary binder in concrete and mortar, binding aggregates and filling voids to form a compact mass. Different types are used based on specific conditions. In this research, Portland Pozzolana Cement (PPC), as per IS 8112:1989, is used for experiments. Table 3.1.1 and Table 3.1.2 illustrate the cement engineering properties utilized in this paper.

Table 3.1.1

Chemical Properties	
SiO_2 (Silica)	21.23
Al_2O_3 (Aluminium Oxide)	3.21
Fe_2O_3 (Iron Oxide)	1.42
MgO (Magnesium Oxide)	3.21
CaO (Calcium oxide)	62.8
K_2O (potassium oxide)	0.9
Na_2O (Sodium oxide)	0.96
SO_3 (Sulphur trioxide)	2.22

Table 3.1.2

Engineering properties	
Normal consistency	32%
Initial setting time	45 minutes
Final setting time	595 minutes
Specific gravity	3.15

3.1.2 FINE AGGREGATE: Fine aggregates pass through a 4.75 mm IS sieve and contain limited coarse particles as per standards. Based on particle size, they are classified as fine, medium, and coarse sands. IS 383:1970 divides fine aggregates into four grading zones, with sand becoming finer from Zone-I to Zone-IV. In this study, locally available river sand (medium sand) with a fineness modulus of 2.87, conforming to Zone-II of IS 383:1970, is used.

3.1.3 COARSE AGGREGATE: Coarse aggregates, retained on a 4.75 mm IS sieve, contain limited fine particles as per code standards. Their chemical properties and mineral composition are derived from parent rocks through natural disintegration. Aggregate sizes include 40 mm, 20 mm, 16 mm, 12.5 mm, and 10 mm. In this research, coarse aggregates are graded as per IS 2386 (Part 1):1963, with a nominal maximum size of 20 mm used for concrete specimens.

3.1.4 GLASS POWDER: Industrial waste glass is crushed into fine powder rich in SiO_2, giving it pozzolanic properties. To minimize the risk of Alkali-Silica Reaction, glass powder finer than 75 microns is used.

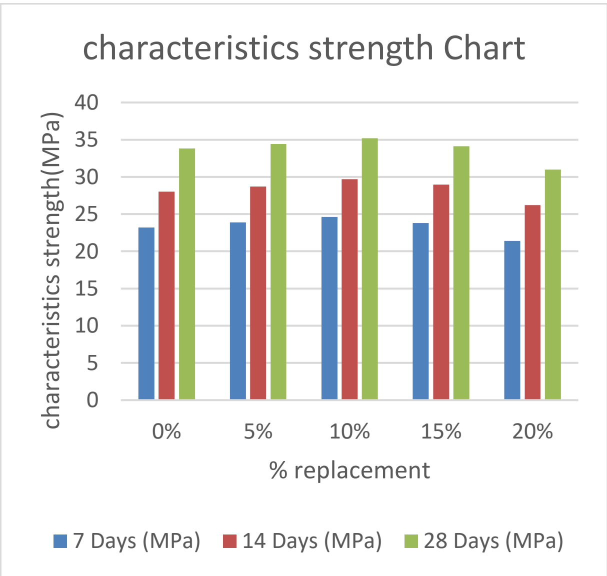
Table 3.1.4

Chemical Properties	
SiO2 (Silica)	70.82%
Al2O3 (Aluminium Oxide)	2.22%
Fe2O3 (Iron Oxide)	0.51%
MgO (Magnesium Oxide)	1.41%
CaO (Calcium oxide)	10.82%
Na2O (Sodium oxide)	12.95%
SO3 (Sulphur trioxide)	0.10%

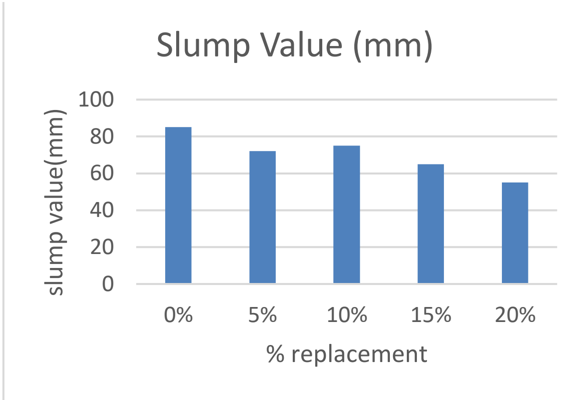
3.1.5 WATER: Water is a crucial and economical component of concrete, aiding in cement hydration, improving workability, and enabling proper curing, which affects concrete durability. In this study, potable water, as per IS 456:2000, is used for mixing and curing.

4. RESULT AND DISCUSSION

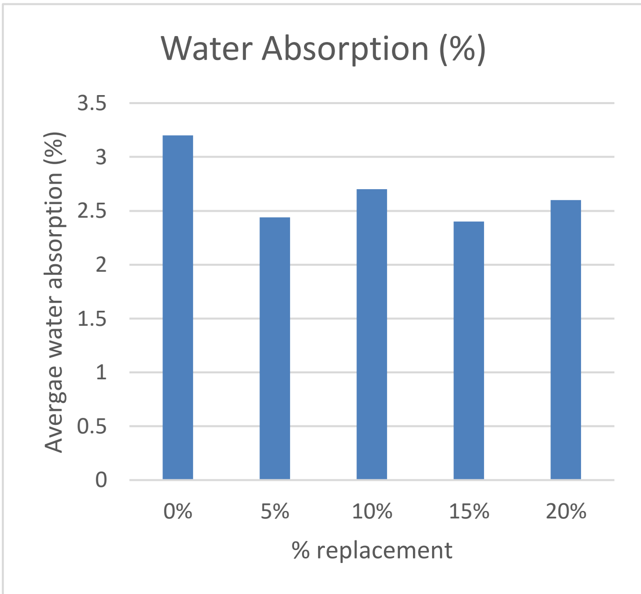
4.1 COMPRESSIVE STRENGTH: The bar graph displays the characteristic strength at 0%, 5%, 10%, 15%, and 20% replacement. Strength increases over time (7, 14, 28 days) for all percentages. The 28-day strength is consistently highest. Strength varies with replacement percentage, peaking around 5% and generally decreasing at higher percentages.



4.2 WORKABILITY: The line graph illustrates the slump value of a material at varying percentages of groundnut powder (GP) replacement, ranging from 0% to 20%. The graph reveals a general downward trend in slump value as the percentage of GP replacement increases. Initially, the slump value is highest with no GP replacement. As the percentage of GP replacement increases to 5%, the slump value decreases. A slight increase in slump is observed at 10% replacement before it continues to decline at 15% and reaches its lowest point at 20% GP replacement. This suggests that the addition of groundnut powder generally reduces the workability or consistency of the material, as indicated by the decreasing slump values.



4.3 WATER ABSORPTION: The bar graph presents the water absorption test results across three trials and their average. The first trial shows a certain level of water absorption. The second trial indicates a lower water absorption compared to the first. The third trial shows a water absorption level that falls between the first and second trials. The average water absorption across the three trials is also depicted.



5. CONCLUSIONS

The incorporation of waste glass powder (WGP) as a partial replacement for cement in concrete presents a viable and sustainable solution to address both environmental and material challenges in the construction industry. Based on the experimental findings, the following conclusions can be drawn:

Replacing cement with WGP up to 10% significantly improves the compressive strength of concrete, reaching 35.2 MPa at 28 days, compared to 33.8 MPa for the control mix. This enhancement is attributed to the pozzolanic reaction between the silica in glass powder and calcium hydroxide, forming additional calcium silicate hydrate (C-S-H).

Workability, however, decreased with increasing WGP content, with slump values dropping from 85 mm (control) to 55 mm (20% WGP). This reduction is due to the angular shape and high surface area of the glass powder, which increases internal friction and water demand.

Water absorption decreased notably with the addition of glass powder. At 15% replacement, the lowest absorption value of 2.4% was recorded, suggesting a denser and less porous concrete matrix, which contributes to enhanced durability.

In summary, waste glass powder can be effectively utilized as a supplementary cementitious material, offering environmental benefits such as reduced cement consumption and glass waste management. The optimal replacement level lies between 10–15%, balancing strength, durability, and workability. However, for higher replacement levels, the use of superplasticizers or other admixtures is recommended to maintain adequate workability.

FUTURE SCOPE research should focus on long-term performance, life-cycle cost analysis, and field-scale implementation to further validate the potential of WGP in sustainable concrete production.

REFERENCES

1. International Journal of Sustainable Building Materials. (2025). Vol. 13(1). Emerging Use of Glass in Eco-Concretes.
2. Tiwari, D. et al. (2025). A Lifecycle Approach to Glass Powder Cement Substitution. Journal of Construction Engineering, 58(1), 75-88.
3. Jain, V., & Roy, S. (2025). Comparative Study of Industrial Wastes in Cementitious Composites. Materials in Civil Engineering, 37(5), 104109.
4. Choudhary, A., & Banerjee, P. (2024). Performance of Concrete Pavements Using Waste Glass. Transportation Infrastructure Journal, 10(2), 110-117.
5. Ali, H. M. et al. (2024). Alkali-Silica Reactivity Mitigation with Glass Powder in Cement. Journal of Advanced Concrete Technology, 22(3), 2024.
6. JETIR. (2024, Feb). Vol. 11, Issue 2. Experimental Validation of Glass Waste in Cement Concrete.
7. JETIR. (2024, April). Vol. 11, Issue 4.
8. Sharma, P., & Thomas, J. (2023). Thermal and Mechanical Properties of Concrete with Waste Glass. Renewable and Sustainable Energy Reviews, 174, 113149.
9. World Economic Forum. (2022). Copernicus Earth System Science Data (2018).
10. Waste Management & Research. (2020). Article reuse guidelines: SAGE Journals,38(11), 1204-1213. https://doi.org/10.1177/0734242X2094.